Ch.2

OSCILLATORS

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2

Resonant (Tuned) Circuit Oscillator

Resonant (Tuned) circuit oscillator

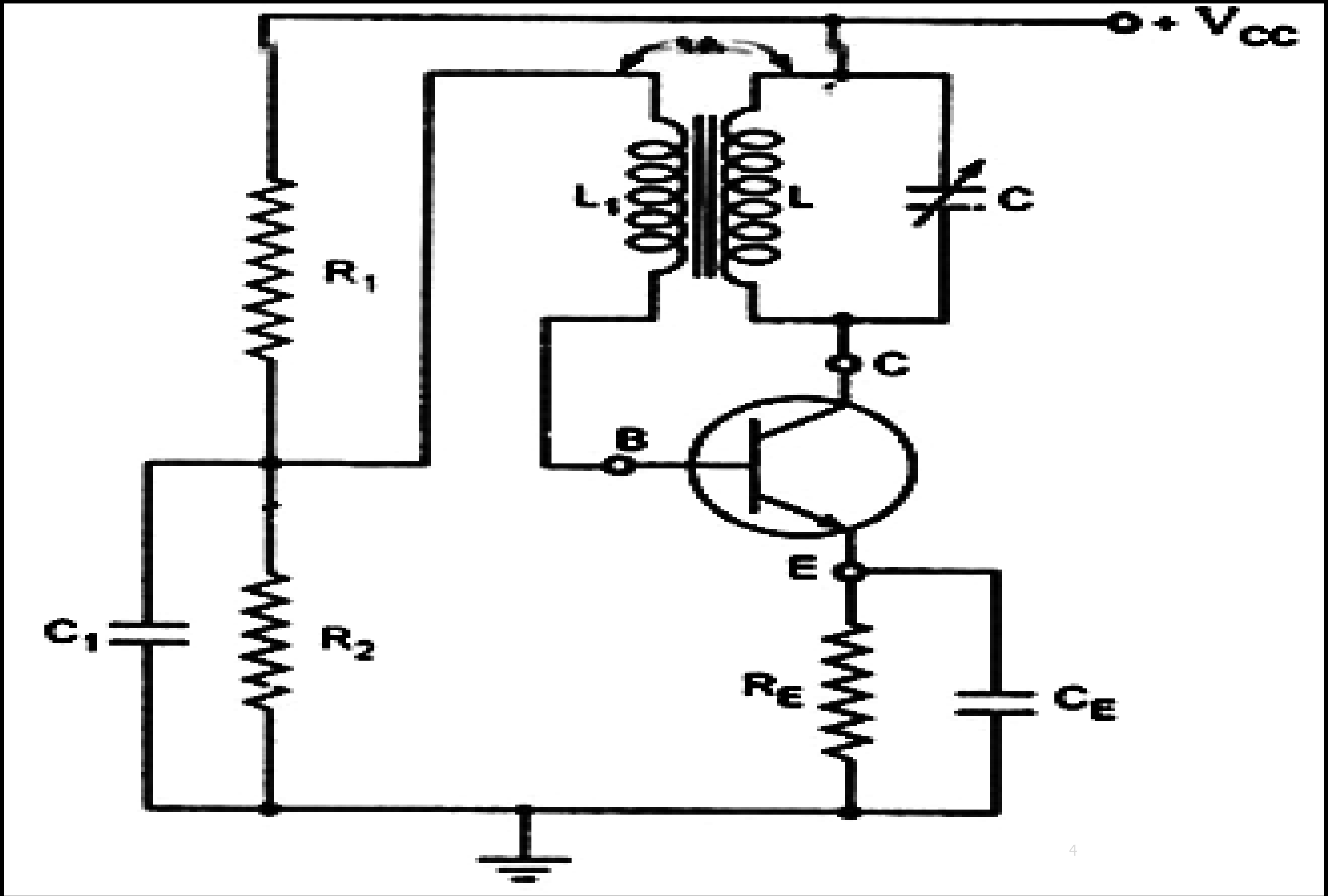
- **In this type of oscillator, a resonant (LC) circuit is used to determine the frequency of oscillation. The resonance circuit constitutes the load impedance of the amplifier. The output developed across the LC circuit is inductively coupled to the input of the amplifier, thus, giving a feedback.**
- **The tuned circuit, constituted by the capacitor C and transformer primary coil, forms the load impedance and determines the frequency of oscillation.**

Resonant (Tuned) circuit oscillator

Figure 2.6:
Resonant oscillator circuit employing a transistor

or

Tuned Collector Oscillator



What is a Bypass Capacitor?

http://www.learningaboutelectronics.com/Articles/What-is-a-bypass-capacitor

Another phase shift of 180° is provided by the transformer. Thus a total phase shift of 360° appears between the input and output voltages i.e., there is a positive feedback between the input and output voltages.

The transistor amplifier provides sufficient gain for oscillator action to take place.

Higher is the turn-ratio, lesser is the feedback voltage applied and vice-versa.

There are two common types of the resonant circuit oscillators:

Hartley

- The resonant circuit is a tapped inductor or two inductors and one capacitor

Colpitts

- The resonant circuit is an inductor and two capacitors.

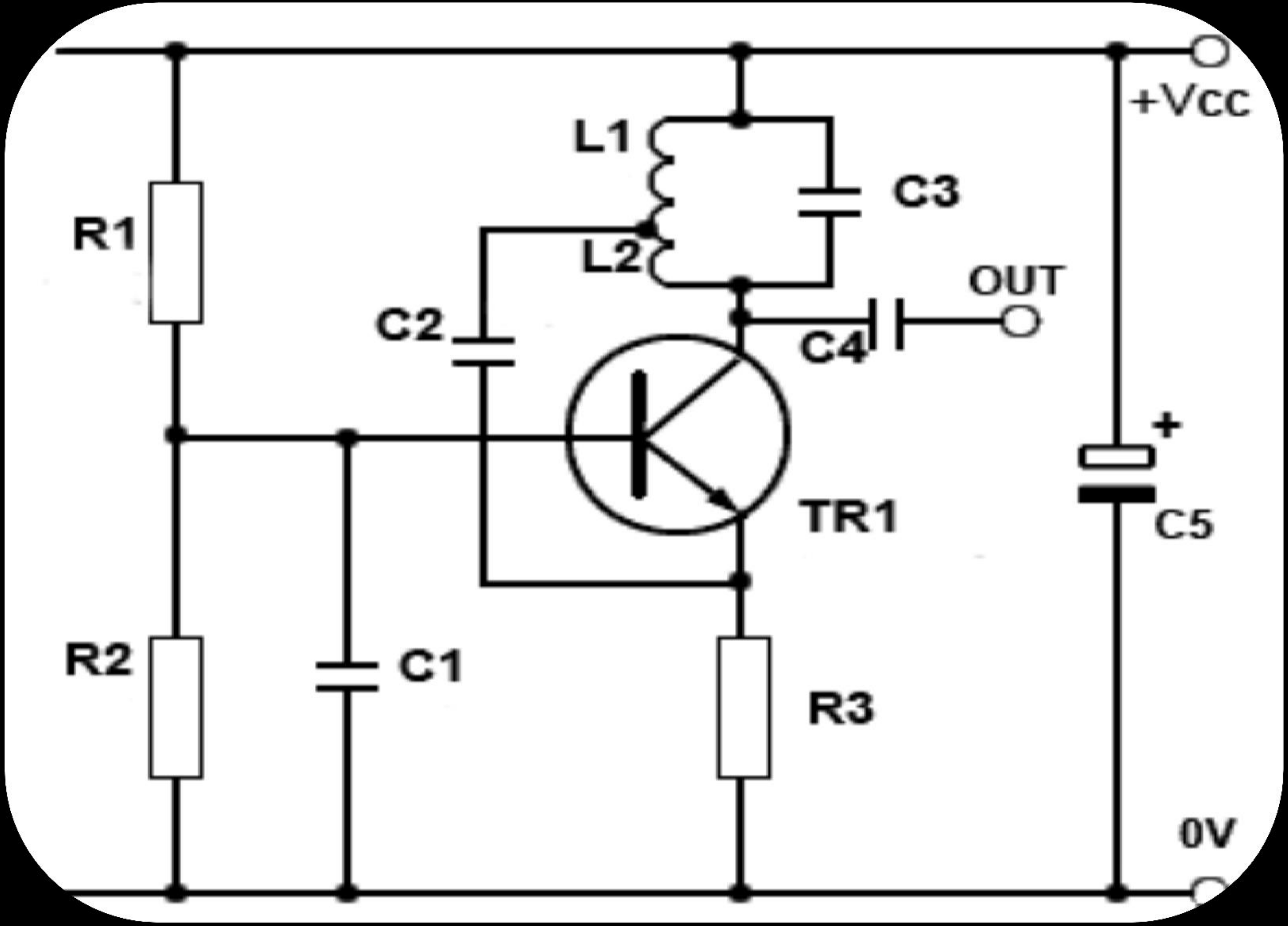
Hartley Oscillator

The Hartley Oscillator is a particularly useful circuit for producing good quality sine wave signals in the RF range, (30 kHz to 30 MHz) although at the higher limits of this range and above, The Colpitts oscillator is usually preferred.

The Hartley design can be recognized by its use of a tapped inductor (L_1 and L_2 in Fig.).

Hartley Oscillator

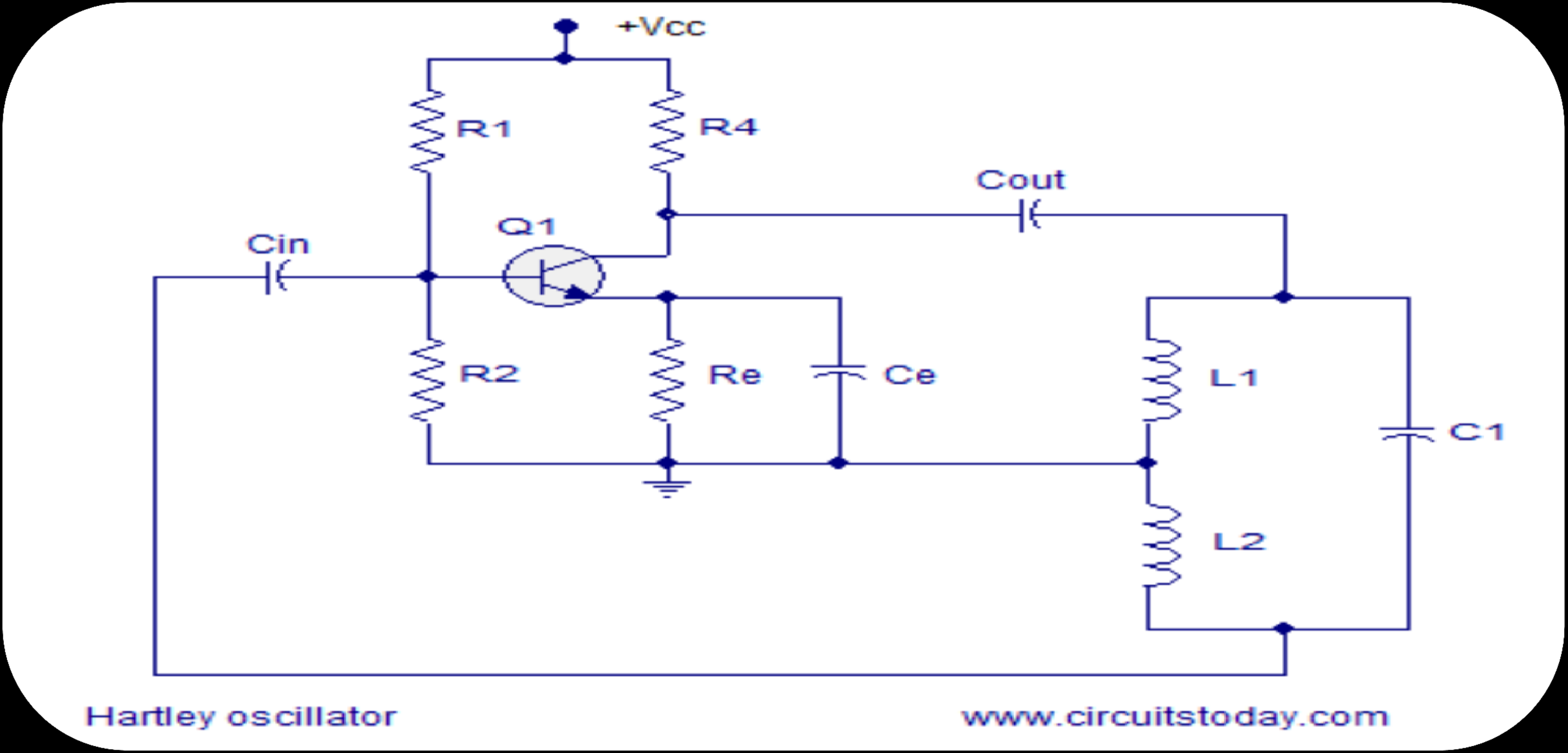
The frequency determining resonant tuned circuit is formed by L_1/L_2 and C_3 and is used as the load impedance of the amplifier.



common base amplifier

This gives the amplifier a high gain only at the resonant frequency.

Hartley Oscillator



Hartley Oscillator

The frequency of oscillation can be calculated in the same way as any parallel resonant circuit, using:

$$f_r = \frac{1}{(2\pi\sqrt{LC})}$$

Where $L = L_1 + L_2$

Hartley Oscillator

In this mode the output voltage waveform at the collector, and the input signal at the emitter are in phase.

C_2 also forms a long time constant with the emitter resistor R_3 to provide an average DC voltage level proportional to the amplitude of the feedback signal at the emitter of TR_1. This is used to automatically control the gain of the amplifier to give the necessary closed loop gain of 1.

How the Hartley oscillator works?

http://www.circuitstoday.com/hartley-oscillator

When the oscillator is first powered up, the amplifier is working in class A with positive feedback.

The LC tank circuit receives pulses of collector current and begins to resonate at its designed frequency.

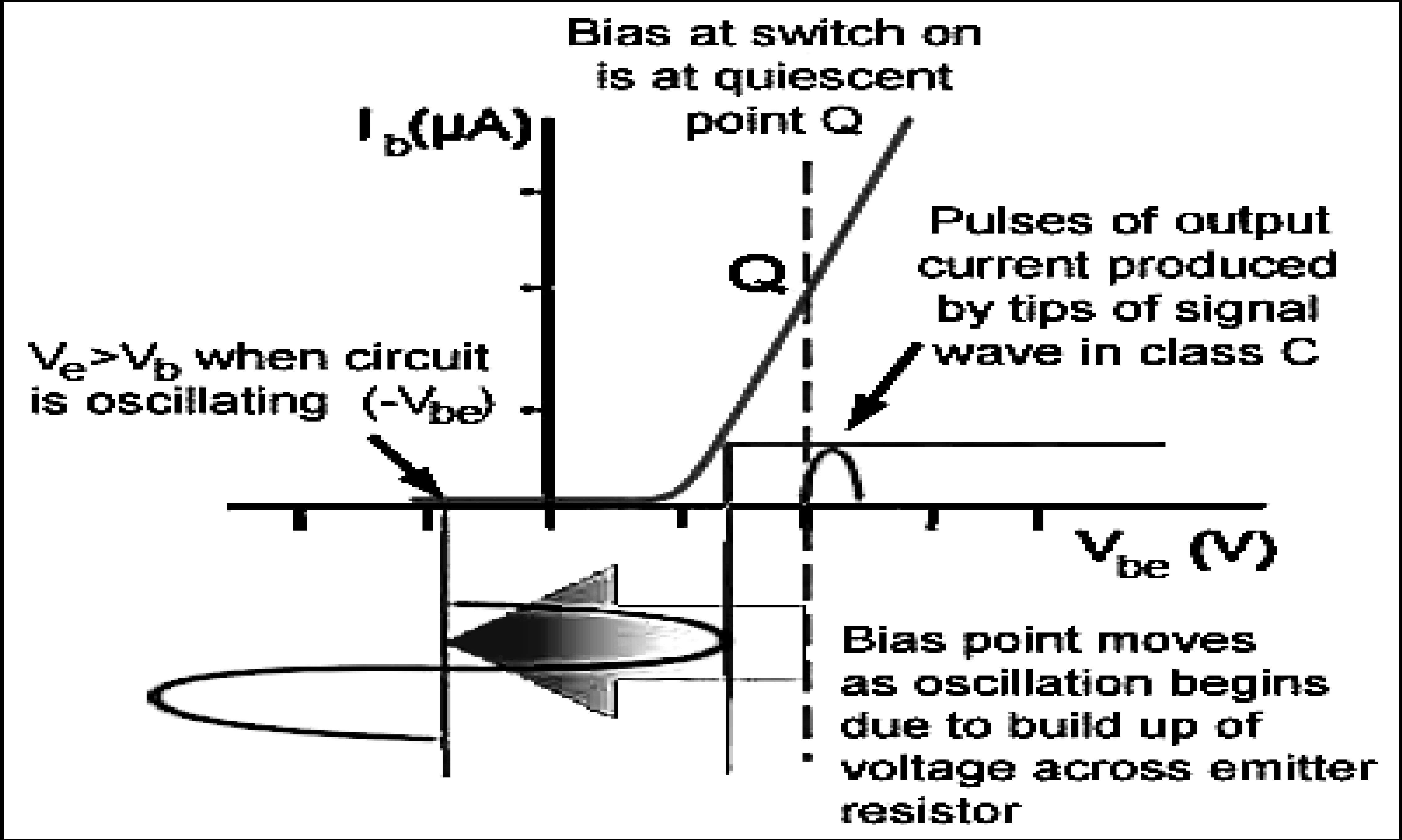
The current magnification provided by the tank circuit is high, which initially makes the output amplitude very large.

However, once the first pulses are present and are fed back to the emitter via C_2, a DC voltage, dependent to a large extent on the time constant of C_2 and R_3, which is much longer than the periodic time of the oscillator wave, builds up across R_3.

As the emitter voltage increases, the bias point of the amplifier ‘slides’ from its class A position towards class C conditions, as shown in Fig 2.8, reducing the difference (V_{be}) between the relatively stable base voltage created by the potential diver R_l/R_2 and the increasingly positive emitter voltage.

This reduces the portion of the waveform that can be amplified by TR_1, until just the tips of the waveform are producing pulses of collector current through the tank circuit and the closed loop gain circuit has reduced to 1.

Effectively the positive feedback from the tank circuit and the negative and feedback created by C_2 and R_3 are in balance.


Bias at switch on
is at quiescent
point Q
$I_b(\mu A)$
Q
Pulses of output
current produced
by tips of signal
wave in class C
$V_e > V_b$ when circuit
is oscillating $(-V_{be})$
V_{be} (V)
Bias point moves
as oscillation begins
due to build up of
voltage across emitter
resistor

Any deviation from this balance creates a correcting effect. If the amplitude of the output wave reduces, the feedback via C_2 also reduces causing the emitter voltage to decrease, making negative value of V_{be} less, and so creating a correcting increase in collector current and a greater output wave produced across the tank circuit. As collector current increases, the TR_1 emitter voltage will do also. This will cause a larger voltage across R_3 making the emitter more positive, effectively increasing the amount of negative base/emitter voltage of TR_1. This reduces collector current again, leading to a smaller output waveform being produced by the tank circuit and balancing the closed loop gain of the circuit at 1.

Example

A Hartley Oscillator circuit having two individual inductors of 0.5mH for each is designed to resonate in parallel with a variable capacitor that can be varied from 100pF to 500pF. Determine the upper and lower frequencies of oscillation and also the Hartley oscillator bandwidth.

The frequency of oscillations for a Hartley Oscillator is given as:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$L_T = L_1 + L_2 = 0.5mH + 0.5mH = 1.0mH$$

$$f_H = \frac{1}{2\pi\sqrt{1mH \times 100pF}} = \frac{1}{6.283\sqrt{1\times10^{-13}}} = 503228\,Hz$$

$$\therefore f_H = 503kHz$$

$$f_L = \frac{1}{2\pi\sqrt{1mH \times 500pF}} = \frac{1}{6.283\sqrt{5\times10^{-13}}} = 225050\,Hz$$

$$\therefore f_L = 225kHz$$

$$\text{Bandwidth} = f_H - f_L$$

$$= 503 - 225 = 278kHz$$

Colpitts Oscillator

The Colpitts circuit, like other LC oscillators, consists of a gain device (such as a bipolar junction transistor, field effect transistor, operational amplifier, or vacuum tube) with its output connected to its input in a feedback loop containing a parallel LC circuit (tuned circuit) which functions as a bandpass filter to set the frequency of oscillation.

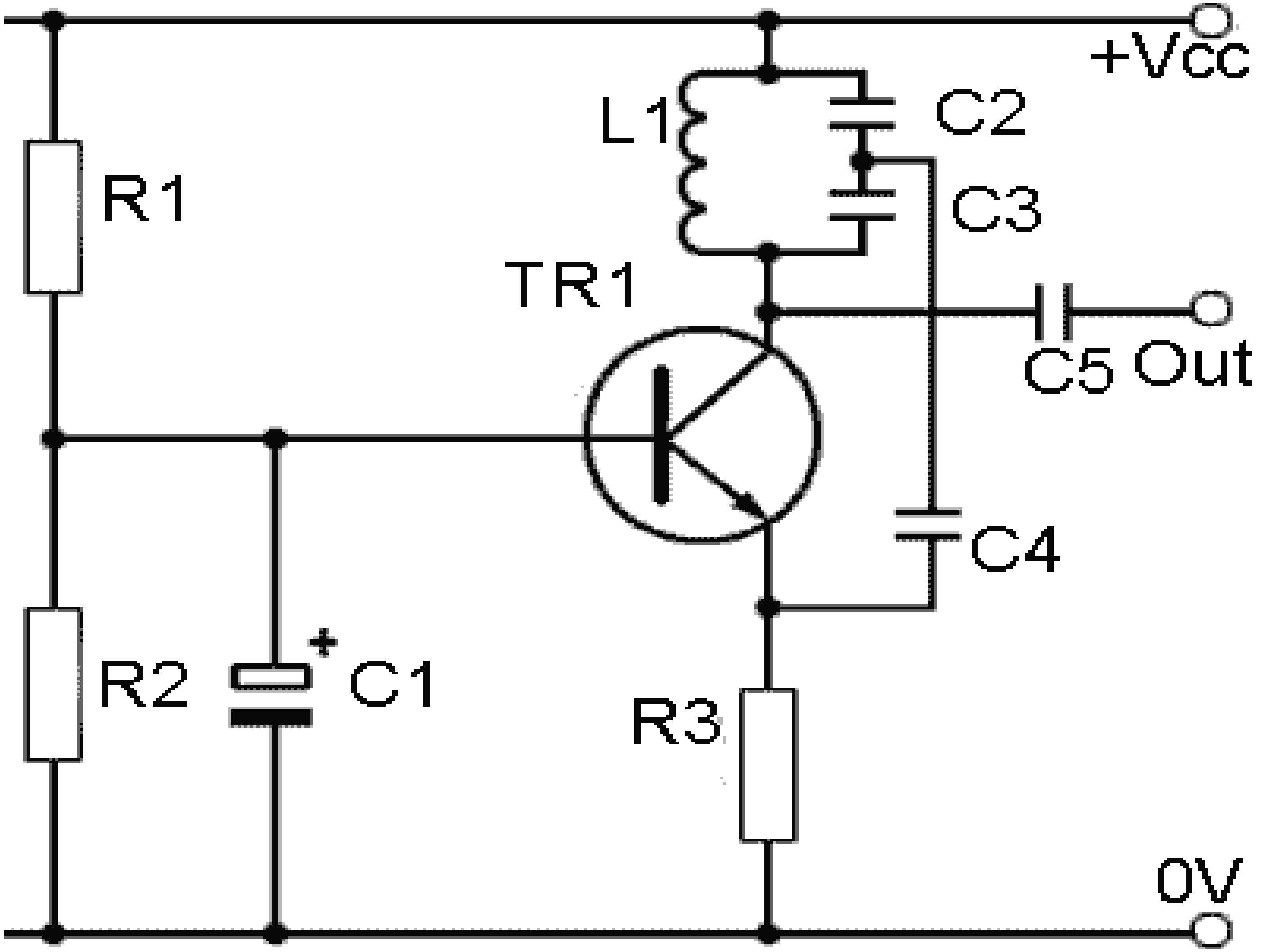


Fig. 2.3.1 The Common Base Colpitts Oscillator

http://www.learnabout-electronics.org/Oscillators/osc23.php

Colpitts Oscillator

This circuit is very similar in operation to the Hartley oscillator but the Colpitts LC tank circuit consists of a single inductor and two capacitors. The capacitors form in effect, a single 'tapped' capacitor instead of the tapped inductor used in the Hartley. The values of the two capacitors (connected in series) are chosen so their total capacitance in series (C_{TOT}), is given by:

$$C_{TOT} = \frac{C_2 \times C_3}{C_2 + C_3}$$

$$f_r = \frac{1}{(2\pi\sqrt{LC})}$$

Colpitts Oscillator

The main advantage of the Colpitts arrangement, is that the single inductor in the tuned circuit removes the effect of any mutual inductance between two coils where the alternating magnetic field built up around one inductor induces a current into the their inductor. This would affect the total inductance of the coils and so changes the resonant frequency of the tuned circuit.

Example

A Colpitts Oscillator circuit having two capacitors of 10pF and 100pF respectively are connected in parallel with an inductor of 10mH. Determine the frequency of oscillations of the circuit.

3 Wien Bridge Oscillator

Wien Bridge Oscillator

One of the simplest sine wave oscillators which uses a RC network in place of the conventional LC tuned tank circuit to produce a sinusoidal output waveform, is the Wien Bridge Oscillator.

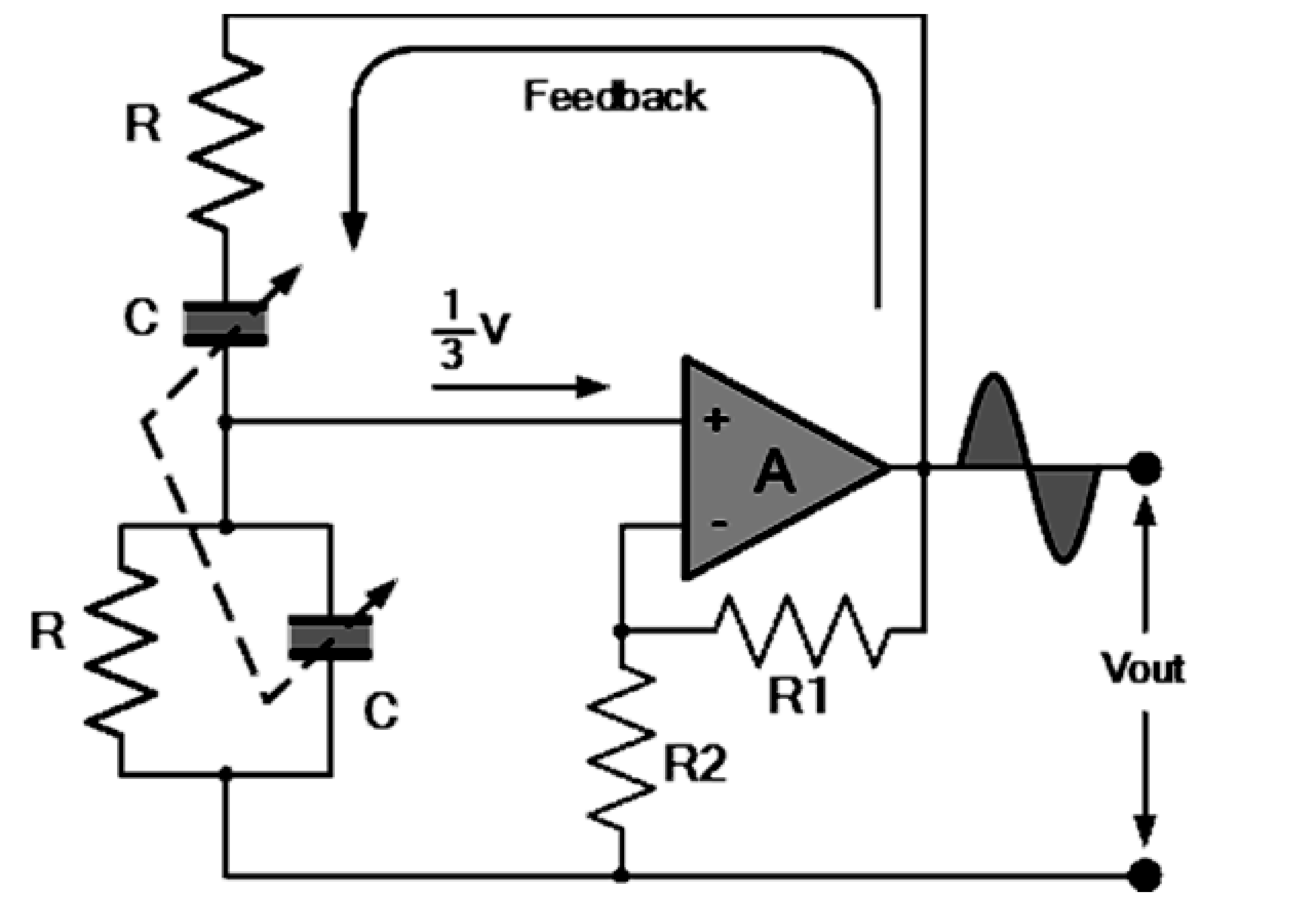
It can generate a large range of frequencies.

The oscillator is based on a bridge circuit originally developed by Max Wien in 1891.

Wien Bridge Oscillator

The Wien bridge oscillator can be considered as a combination of a differential amplifier and a Wien bridge, connected in a positive feedback loop between the op-amp output and differential input. At the oscillating frequency, the bridge is almost balanced and has very small transfer ratio. The loop gain is a product of the very high op-amp gain and the very low bridge ratio. The frequency of oscillation is given by:

$$f = \frac{1}{2\pi RC}$$


Feedback
R
C
$\frac{1}{3}$V
+
A
-
R
C
R1
R2
Vout

Wien Bridge Oscillator

The output of the operational amplifier is fed back to both the inputs of the amplifier. One part of the feedback signal is connected to the inverting input terminal (negative feedback) via the resistor divider network of R_1 and R_2 which allows the amplifiers voltage gain to be adjusted within narrow limits. The other part is fed back to the non-inverting input terminal (positive feedback) via the RC Wien Bridge network.

It is a low frequency oscillator which ranges from a few kHz to 1 MHz.

Wien Bridge Oscillator

The RC network is connected in the positive feedback path of the amplifier and has zero phase shift a just one frequency. Then at the selected resonant frequency, (f_r) the voltages applied to the inverting and non-inverting inputs will be equal and "in-phase" so the positive feedback will cancel out the negative feedback signal causing the circuit to oscillate.

Also the voltage gain of the amplifier circuit MUST be equal to three "Gain = 3" for oscillations to start. This value is set by the feedback resistor network, R_1 and R_2 for an inverting amplifier and is given as the ratio $-R_1/R_2$. Also, due to the open-loop gain limitations of operational amplifiers, frequencies above 1MHz are unachievable without the use of special high frequency op-amps.

We can summarize the Wien Bridge Oscillator in the following:

1. With no input signal the Wien Bridge Oscillator produces output oscillations.
2. The Wien Bridge Oscillator can produce a large range of frequencies.
3. The Voltage gain of the amplifier must be at least 3.
4. The network can be used with a Non-inverting amplifier.
5. The input resistance of the amplifier must be high compared to R so that the RC network is not overloaded and alter the required conditions.
6. The output resistance of the amplifier must be low so that the effect of external loading is minimized.
7. Some method of stabilizing the amplitude of the oscillations must be provided because if the voltage gain of the amplifier is too small, the desired oscillation will decay and stop, and if it is too large, the output amplitude rises to the value of the supply rails, which saturates the op-amp and causes the output waveform to become distorted.
8. With amplitude stabilization in the form of feedback diodes, oscillations from the oscillator can go on indefinitely.

What is the difference between wien-bridge oscillator and phase-shift oscillator ?

5.26.2.2 Advantages

The various advantages of Wien bridge oscillator are,

1. By varying the two capacitor values simultaneously, by mounting them on the common shaft, different frequency ranges can be obtained.

2. The perfect sine wave output is possible.

3. It is useful audio frequency range i.e. 20 Hz to 100 kHz.

5.26.2.3 Disadvantages

If instead of op-amp, transistorised amplifier is to be used then more stages are required to obtain 0° phase shift between input and output. This increases the number of components and cost. The frequency stability is poor.

Types of oscillators

1. RC oscillators
   - Wien Bridge
   - Phase-Shift
2. LC oscillators
   - Hartley
   - Colpitts
   - Crystal
3. Unijunction / relaxation oscillators

Report

RC feedback oscillators are generally limited to frequencies of 1 MHz or less.
LC oscillators are for hundreds of kHz to hundreds of MHz frequency range.

Thank You

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